Characterizing Visual Performance During Approach and Landing With and Without a Synthetic Vision Display: A Part Task Study

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Abstract

A part-task simulation study of commercial transport approach and landings operations with and without a synthetic vision system (SVS) was conducted in order to generate empirical data and descriptive information for the development of cognitive models of this task environment. Control inputs, eye-tracking, questionnaire, and video recording data were collected from three airline pilots operating over a variety of event and visibility conditions. A description of the simulation configuration, the scenarios tested, and the output data distributed to 5 modeling teams for subsequent analyses is presented. Of primary interest were the eye-tracking data and the observed changes in visual performance associated with the availability of the SVS display. A summary of measures characterizing the distribution, frequency, and duration of the pilots' visual attention during the nominal landing trials (a subset of the scenarios tested) is presented to illustrate the type of analyses that the study data supports. From this summary, regularities in scanning behavior with and without the SVS display are noted, as are localized differences in individual usage strategies.

Introduction

Background

The convergence of several key technologies has accelerated the development and testing of synthetic vision systems (SVS) which provide pilots with an always-available computer-generated perspective view of the outside world ahead of their aircraft. Such a capability affords enhanced spatial and terrain awareness during both darkness and poor visibility. This would especially benefit safety during approach and landing operations when knowing one's position relative to nearby terrain, obstacles, and the runway is always of critical importance. The continued occurrence in both commercial and general aviation of controlled-flight-into terrain (CFIT) accidents and controlled-flight-toward-terrain (CFTT) incidents (Flight Safety Foundation, 1998) attest to this importance.

Though considerable research has been devoted to implementation and design aspects of synthetic vision such as display size, field of view, optimal scene texturing, and appropriate symbology (for summaries, see Purcell, Corker, & Guneratne, 2002; Norman, 2002), less is known about the impact that these systems might have on general flight deck operations. Motivating the present part-task study and corresponding modeling efforts is the recognition that the deployment of new flight deck technologies sometimes alters the manner in which pilots carry out tasks, often in ways that were not fully anticipated by designers (Billings, 1996: Woods & Dekker, 2000). These unanticipated usage patterns can lead to adverse operational consequences.

Clearly, the introduction of a SVS display changes the informational landscape of the flight deck by providing a new and rich source of visual-spatial information. For this reason, an appropriate research issue concerns how pilots will adjust their visual performance to this enlarged landscape. That is, what changes will pilots make in where they look, how long they look, and the sequences in which they look at available informational sources? Gaining a better understanding of how pilots alter their visual performance when flying with a SVS display should help inform the design of effective operational procedures and highlight potential sources of error.

Purpose

The objective of the present study was to generate empirical data and descriptive information regarding pilot performance during approach and landing, with and without the use of a synthetic vision display, for the development of cognitive models of this task environment. (See Foyle, Goodman, and Hooey [2003] in this volume for an overview of the Human Performance Modeling element which this effort supported). The remainder of this paper will describe the details of the part-task simulation study, clarify output data and information made available for model development, and provide an illustrative summary of observed pilot visual performance.

Method

Participants

Three currently flying airline pilots[1] participated in the simulation study. Included in the demographic information collected from the participants was an assessment of prior experience with terrain awareness displays and head-up displays. This was of interest as both display types require pilots to interpret superimposed symbology over terrain information, a task similar to what was required in utilizing the SVS display introduced in this study. Participant demographic information is presented below in Table 1.

Table 1. Demographic information of pilots participating in simulation study.

	Current Crew Position	Current Aircraft Operated	Total Flight Hours	Terrain Awareness Display Hrs.	Head-Up Display Use Hours
Pilot 3	Captain	B-757 / B-767	≈ 16,000	≈ 2000	0
Pilot 4	First Officer	B-747-400	≈ 12,000	0	0
Pilot 5	Captain	B-757 / B-767	≈ 11,000	≈ 1500	≈ 100

Simulator

A PC-based part-task simulator was constructed using the NASA developed PC Plane software package (Palmer, Abbott, & Williams, 1997) which approximated the instruments, controls, and flight characteristics of a Boeing-757. This was linked with an X-IG© 3-D image generation system employing a visual database of Santa Barbara Municipal Airport (SBA) and its surrounding terrain. The simulated flight deck consisted of 6 display components as shown below in Figure 1. Pilot control inputs were made via a joystick with throttle lever, and touchscreen software buttons. A more explicit view of the simulation displays is provided by the photograph shown in Figure 2.

[1] Delineated here as Pilots 3, 4, and 5 which is consistent with other papers in this volume (Pilots 1 and 2 served as simulation check-out pilots and their data is not reported)

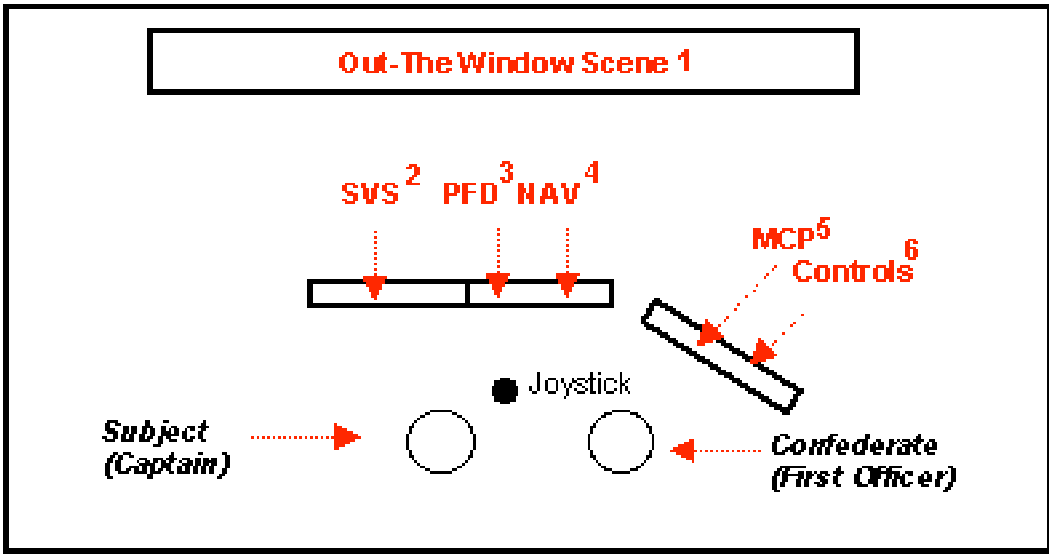

Figure 1. Plan-view diagram of simulation configuration with numbered labels referencing descriptions provided in Displays section of this paper.

Figure 2. Photograph of simulation displays taken from pilot's eye perspective.

Displays

1. Out-the-Window (OTW): The visual out-the-window scene (shown in Figure 3) was presented on a large front projection screen measuring 8 feet horizontal (H) and 6 feet vertical (V) located approximately 8 feet in front of participating pilots. Taking into account the obscuration caused by the front panel of the simulated flight deck, the OTW display provided pilots a 54.6˚ H and 34.9˚ V field of view of the forward external world. On-screen visibility varied between zero visibility and clear visibility according to scenario specifications as detailed in the study design section.

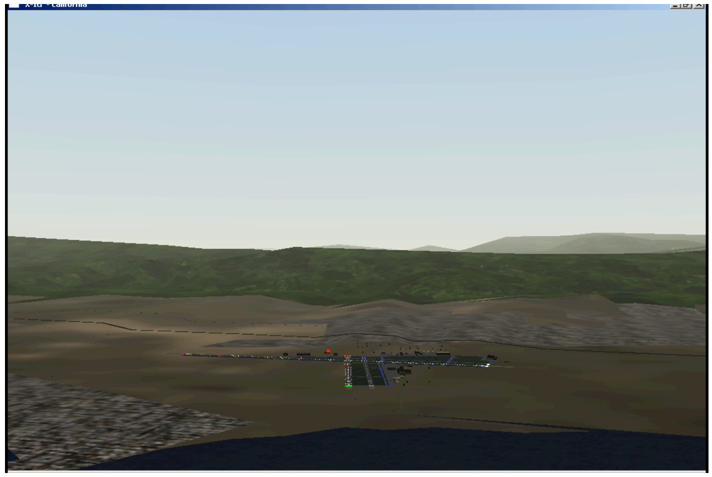

Figure 3. Out-the-Window Scene approaching Runway 33L at Santa Barbara Airport in VMC conditions.

2. Synthetic Vision System (SVS): The SVS was implemented on a large format head-down display measuring 10 inches H by 7.5 inches V and located 34 inches from pilot eye-point (16.7˚ H, 12.6˚ V). The display presented computer-generated 3-D color imagery of terrain and cultural features overlaid with flight-director symbology, including a flight path predictor (see figure 4). The field of view of the presented imagery was set at 31˚ H and 23˚ V, which provided a somewhat "wide-angle" perspective relative to unity. This fixed field of view was chosen as a good compromise setting, falling between the wide-angle 60˚ horizontal field of view that research had shown (Comstock, Glaab, Prinzel, & Elliot, 2001) was preferred by pilots during early approach phases and the unity field of view desired at landing.

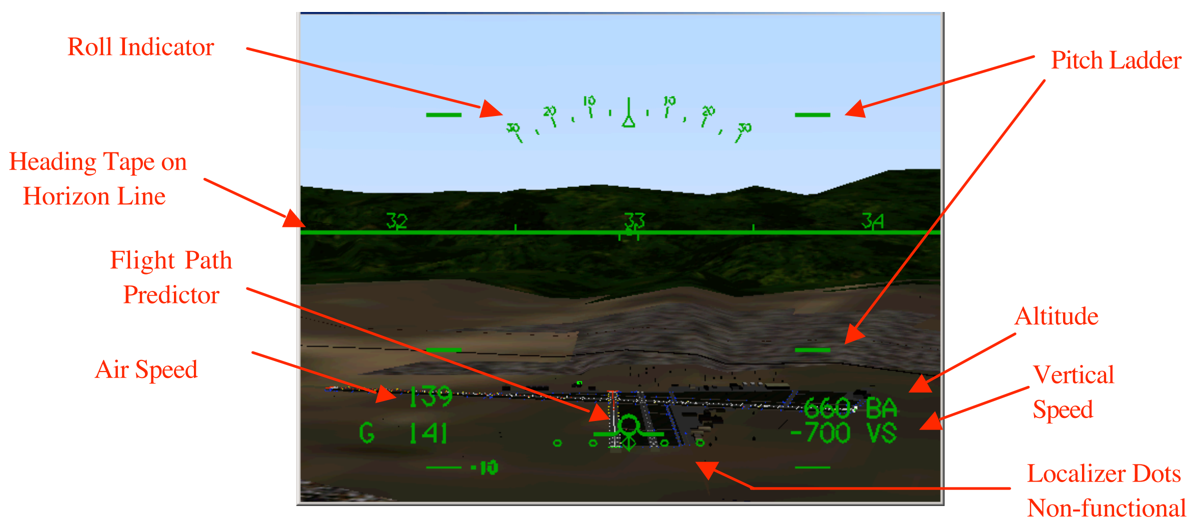

Figure 4. SVS display with identified symbology shown at decision height (DH) on approach to runway 33L at Santa Barbara.

3. Primary Flight Display (PFD): A conventional primary flight display (see Figure 5) measuring 5.25 inches H and 5.25 inches V was located 34 inches from pilot eye-point (3.1˚ H, 3.1˚ V). The display provided information specifying air speed, attitude, current and

targeted altitude, vertical speed, engine pressure ratios (EPR), distance to next waypoint, and flight mode annunciation

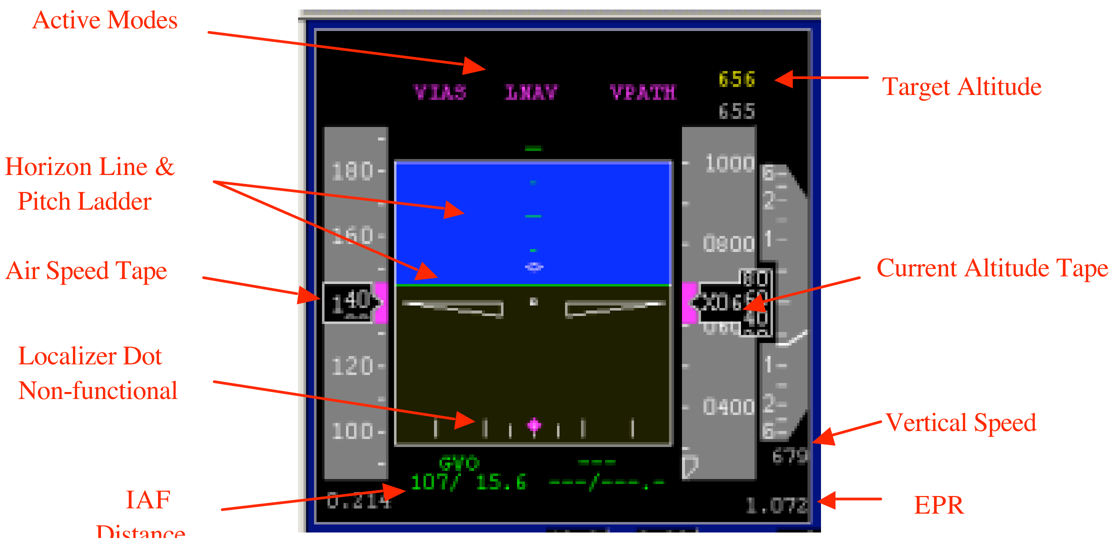

Figure 5. Primary Flight Display (PFD) as seen in simulation.

4. Navigation Display (NAV): A conventional navigation display (see Figure 6) measuring 5.25 inches H and 5.25 inches V was located 34 inches from pilot eye-point (3.1 deg H, 3.1 deg V). The display provided information specifying ownship track, current heading, latitude/longitude of current position, previous and next fix, distance to next fix, range arcs, and descent crossing arcs.

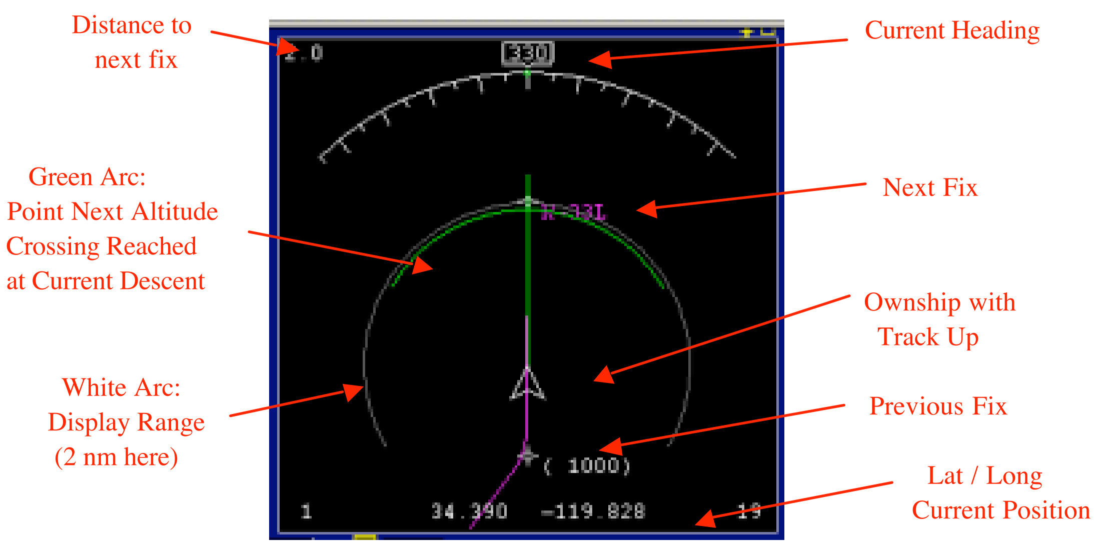

Figure 6. Navigation display (NAV) as seen in simulation.

5. Mode Control Panel (MCP): A B-757 type mode control panel (see Figure 7) measuring 13.5 inches H and 3.0 inches V was located 39 inches from pilot eye-point (9.2˚ H, 2.0˚ V). The display provided both the status and the means to control autoflight functions through mouse-controlled or touchscreen inputs.

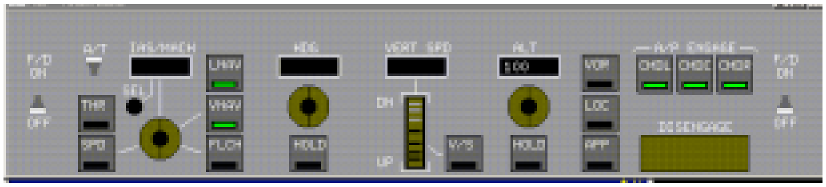

Figure 7. Mode control panel as presented in simulation.

<u>6. Controls:</u> An unconventional display (see Figure 8) measuring 10.5 inches H and 1 inch V (7.2˚ H, 0.7˚ V) was situated below the MCP. The display provided status information and mouse or touchscreen activation of landing gear, flap setting, speed brake, throttle setting, and NAV map scale.

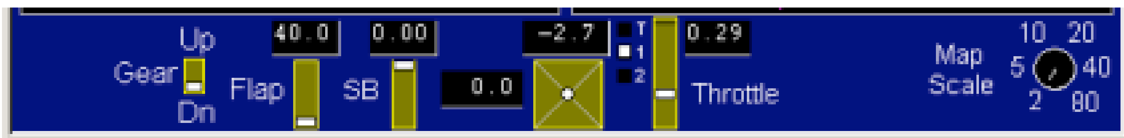

Figure 8. Controls panel as presented in simulation.

Confederate First Officer (FO)

A flight-qualified member of the experimental study team acted as first officer so as to approximate realistic crew procedures and allocation of duties. These duties included acting on all MCP and control inputs specified by captain, making appropriate call-outs, and handling Air Traffic Control (ATC) communications.

Confederate ATC

A second experimental study team member assumed the role of ATC and provided approach and landing clearances for each trial and, once per testing block, a late reassignment of runway. In no instance did ATC vector aircraft off the programmed route, nor was communications to other aircraft (party line communications) simulated.

General Scenario Description

In all study scenarios pilots performed an Area Navigation (RNAV) daylight approach to Runway 33L at Santa Barbara Airport under calm winds. As this approach does not actually exist, an approach plate was constructed for the simulation based on other published RNAV (GPS) plates (so designated because a Global Positioning System is required) and briefed to pilots. The flight management system (FMS) was preprogrammed by the study team to reflect the approach so that no pilot interactions with the FMS were required during the simulation trials. It should be noted that this type of approach does not require nor make use of ground-based ILS equipment (glideslope and localizer) and represents a trend in future flight operations towards aircraft-based precision guidance.

All trials began 36 nm inbound from the northwest at 10,000 ft and 250 kts awaiting ATC clearance for approach. Pilots were required to fly the cleared approach fully coupled to the autopilot, using the lateral navigation (LNAV) and vertical navigation (VNAV) automated flight modes down to the 650 ft decision height (DH), at which point they took full manual control. Depending on scenario circumstances, pilots either continued the landing (trials terminating at 50 ft) or declared a missed-approach and executed a go-around (trials terminating when ascent reached 3,000 ft). Individual trials lasted approximately 12 min.

Study Design

Independent Variables

Four variables of interest were investigated in the study: *Display Configuration, Visibility, Approach Event, and Phase of Approach.*

Display Configuration

(1) Baseline: This configuration represented current-day operations with the PFD, NAV, MCP, and Controls panel constituting the flight deck displays.
(2) SVS: This configuration included all displays presented in the baseline configuration with the addition of the SVS display.

Visibility

(1) Visual Meteorological Conditions (VMC): The entire trial was conducted in clear day visual meteorological conditions using visual flight rules.
(2) Instrument Meteorological Conditions (IMC): The trial began in instrument meteorological conditions with zero visibility due to dense cloud ceiling down to 800 ft, at which point the aircraft broke-out into clear visibility.

Approach Event

(1) Nominal Landing: The aircraft was cleared first for approach and then landing without incident.
(2) Late Runway Reassignment: The aircraft was cleared first for approach and then landing, but at 1000 ft ATC requested that the pilot conduct a side-step maneuver to the adjacent parallel runway (33R) due to uncleared traffic remaining on runway 33L. (Note: This event was tested in the study during IMC conditions with the SVS display, though current ATC operations would allow such a maneuver only in VMC.)
(3) Missed Approach: Aircraft was cleared first for approach and then landing. In the VMC condition the confederate FO calls out traffic on runway at 600 ft; in the IMC condition dense cloud cover extended to the ground and there was no breakout as anticipated at 800 ft. Both conditions required the captain to declare a missed-approach and execute a go-around.
(4) Terrain Mismatch: The aircraft was cleared first for approach and then landing but instruments (including SVS display) were laterally off-set by 250 ft from the OTW scene. During training, pilots were instructed to declare a missed-approach and execute a go-around if instruments were determined to be unreliable.

Phase of Approach

Phase	Start and End Point	Altitudes	Duration
Phase 1	Start of Trial – Initial Approach Fix	Crossing at 10,000 ft	≈1.0 min
Phase 2	Initial Approach Fix – Final Approach Fix	10,000 ft – 1,800 ft	≈7.5 min
Phase 3	Final Approach Fix – Decision Height	1,800 ft – 650 ft	≈2.5 min
Phase 4	Decision Height – Scenario End	650 ft – 50 ft	≈1.0 min

These four progressive phases of approach differ not only in duration but in external circumstances and required pilot activities. Within Phase 1, pilots are focused on obtaining approach clearance from ATC and setting-up that approach within the auto-flight system. In Phase 2, pilots closely monitor the progress of the approach and configure the aircraft (i.e., set landing gear, adjust flaps and trim). During Phase 3, pilots flying in IMC conditions "break-out" from the cloud ceiling into full visibility and, for all conditions, pilots must visual acquire the runway and confirm proper alignment. By Phase 4, unlimited forward visibility prevails (except in scenarios #5 and #9 as explained below) and pilots must transition to manual control while maintaining proper runway alignment and descent rate.

Test Conditions

The four approach events listed above were flown in three display/visibility configurations: Baseline VMC (current day displays with clear visibility); Baseline IMC (current day displays with dense cloud ceiling to 800 ft); and, SVS IMC (with dense cloud ceiling to 800 ft). This yielded 10 viable test conditions, or scenarios (as shown in Table 1), which were each flown once by the three subject pilots. Collected data from all trials were segmented for analysis purposes into the four progressive phases of flight.

Table 2. Test Conditions (Asterisks [*] denote scenarios from which data is presented in this paper.)

Display Configuration		Baseline	Baseline	SVS
Visibility		VMC	IMC	IMC
Approach Event	Nominal Approach (nominal landing)	*Scenario #1**	*Scenario #4**	*Scenario #7**
	Late Reassignment (side-step & land)	*Scenario #2*		*Scenario #8*
	Missed Approach (go-around)	*Scenario #3*	*Scenario #5*	*Scenario #9*
	Terrain Mismatch (go-around)		*Scenario #6*	*Scenario #10*

Procedure

Simulation displays, controls, and procedures were reviewed with participating pilots during an orientation briefing. Thereafter, a training flight was flown in Baseline VMC conditions to familiarize participants with aircraft handling, crew coordination issues, and the Santa Barbara Airport approach. On initiation of each trial, participants were instructed to immediately have the FO arm the autopilots, dial down the altitude, and engage LNAV and VNAV. The participant's task, then, was to monitor and supervise the programmed FMS descent and approach, commanding such actions as flaps, speedbrakes, landing gear, and altitude settings. At DH (650 ft) participants took full manual control (stick and throttle) of the aircraft and either attempted the landing (i.e., descent to 50 ft) or declared a missed approach and executed a go-around.

To minimize pilot adjustment problems in switching back and forth between display conditions, the six Baseline scenarios (without SVS) were randomly divided into two testing blocks of three scenarios each, while the four SVS scenarios were randomly grouped into a third testing block. During data collection, pilots first flew a block of Baseline trials followed by the block of SVS trials and concluded with the remaining Baseline block. Prior to the start of each trial, pilots were told only whether they would be in VMC conditions or IMC conditions (with reported ceiling at 800 ft) and whether the SVS display would be available.

Data Collected

Digital output data were recorded for each trial at 20 Hz across 34 time-referenced variables for aircraft position and orientation, aircraft state, and control inputs.

A helmet-mounted Applied Science Laboratories ASL 5000 eye tracker with eye-head integration was used to collect point of gaze data from participating pilots. Eight sceneplanes were defined in terms of x and y coordinates within a 2-D visual plane encompassing the simulation environment, six of which corresponded to the display regions of interest. For each trial, raw eye fixation data was collected and time-stamped so as to synchronize with other digital data. Data was then processed into a tabular listing of dwell-sequences, durations, and intervals. Summary statistics and sequence probability matrixes were then generated.

For each trial a videotape of the pilot's forward view was recorded from the head-mounted eye tracker. The pilot's point of gaze was shown by crosshairs superimposed over the visual scene. These tapes provided a representation of what the pilot was actually seeing at any given point in the simulation. Additionally, for each trial an ambient audio and video recording was produced that depicted displays and control inputs and verbal communications.

Lastly, after each trial a questionnaire was administered in which subjects rated on a 1 - 7 scale various aspects of their perceived workload and situational awareness across each of the four phases of the just completed flight.

The digital output data, the time synchronized eye-track data, the video recording data, and the questionnaire data collected over the 10 scenarios trials flown in simulation by each of the three participating pilots was distributed, unanalyzed, to five modeling teams. This bundle of empirical data and qualitative information was intended as a primary source of guidance for the construction and validation of cognitive models of pilot performance during approach and landing operations with and without augmented aids. Modeling teams were free to parse and analyze the data as best suited for their particular modeling approach and architectural framework. The specifics of these modeling and simulation efforts are detailed in subsequent papers in this volume.

Selected Results

Of particular interest in this study were the eye-tracking data and what they revealed about changes in visual performance associated with the availability of a SVS display. (The other types of data supplied to the modeling teams are not addressed in this paper). A summary of measures characterizing the distribution, frequency, and duration of the pilots' visual attention during the nominal landing trials is reported below to illustrate the kind of analyses that the eye-track data supports. This summary reflects data collected from scenarios 1, 4, and 7 which differ only in the display/visibility conditions in which participating pilots flew, i.e., Baseline VMC vs. Baseline IMC vs. SVS IMC. All the measures are specified in terms of the six visual regions of interest: OTW, SVS, PFD, NAV, MCP, and Controls. As these six regions constituted the principle sources of flight information within the simulation, fixations recorded outside these regions were ignored. For this summary, the distribution of visual attention was measured as the percentage dwell time in one region relative to the total dwell time in all six display regions. Reported dwell counts indicate the number of "visits" to a particular display region as defined by one or more continuous fixations within a region until visual disengagement. Lastly, reported dwell durations reflect the mean length of time per visit to a display region.

The results for each of the measures are presented graphically (Figures 9a, 9b, 10a and 10b) for each pilot by display condition and phase of approach. The figures are arranged into horizontal panels corresponding to phase of approach and consist of 3 separate graphs, one for each participating pilot. Figures 9a and 9b present the distribution of visual attention of pilots during the nominal landing trials. Here the horizontal axis of each graph shows the display region of interest while the vertical axis represents the percentage of overall dwell time spent in that region. Figures 10a and 10b present the durations and dwell counts. The horizontal axis for these graphs, again, shows the region of interest while the vertical axis represents the mean duration in seconds per dwell. Additionally, a number shown next to each data point marker indicates the dwell count or number of visits made to the display region during that phase of flight.

Based on the observed data, a brief discussion highlighting consistencies and differences in visual performance between approach phases, display conditions, and individual pilots is offered. This discussion is organized in terms of display region.

Out-The-Window Usage

A review of Figures 9a and 9b reveals sizable differences in the percentage of time spent gazing OTW between the three pilots and across the three display/visibility conditions. However, one consistency emerging from the phase of flight data is that regardless of the display/visibility condition, all three pilots devoted an increasing percentage of their visual attention OTW as the aircraft progressed towards landing.

During Phases 1 and 2 in which the aircraft descends to 1800 ft, very little time is committed OTW. Since there is zero visibility for the Baseline IMC and the SVS IMC conditions during these first two phases, it would be expected that pilots only make quick visual checks to see if there is an early break-out from the cloud ceiling. This is suggested in the short OTW dwell durations (mean = .6 sec; see Figure 10a) made by the pilots in this situation. Pilots flying Baseline VMC with clear visibility still relegate no more than 6% of their time OTW through Phase 2.

In Phase 3 the aircraft in Baseline IMC and SVS IMC trials break-out into clear visibility at 800 ft and, for all trials, pilots must visually acquire the runway. Not surprisingly, all three pilots spent the most OTW time in Baseline VMC (10%-18%) in which there was clear visibility throughout the entire phase. However, in comparing Baseline IMC and SVS IMC trials, it is seen that Pilot 3 and 4 each devote 7.5% less time OTW when the SVS display is available. Pilot 5 does not exhibit this characteristic.

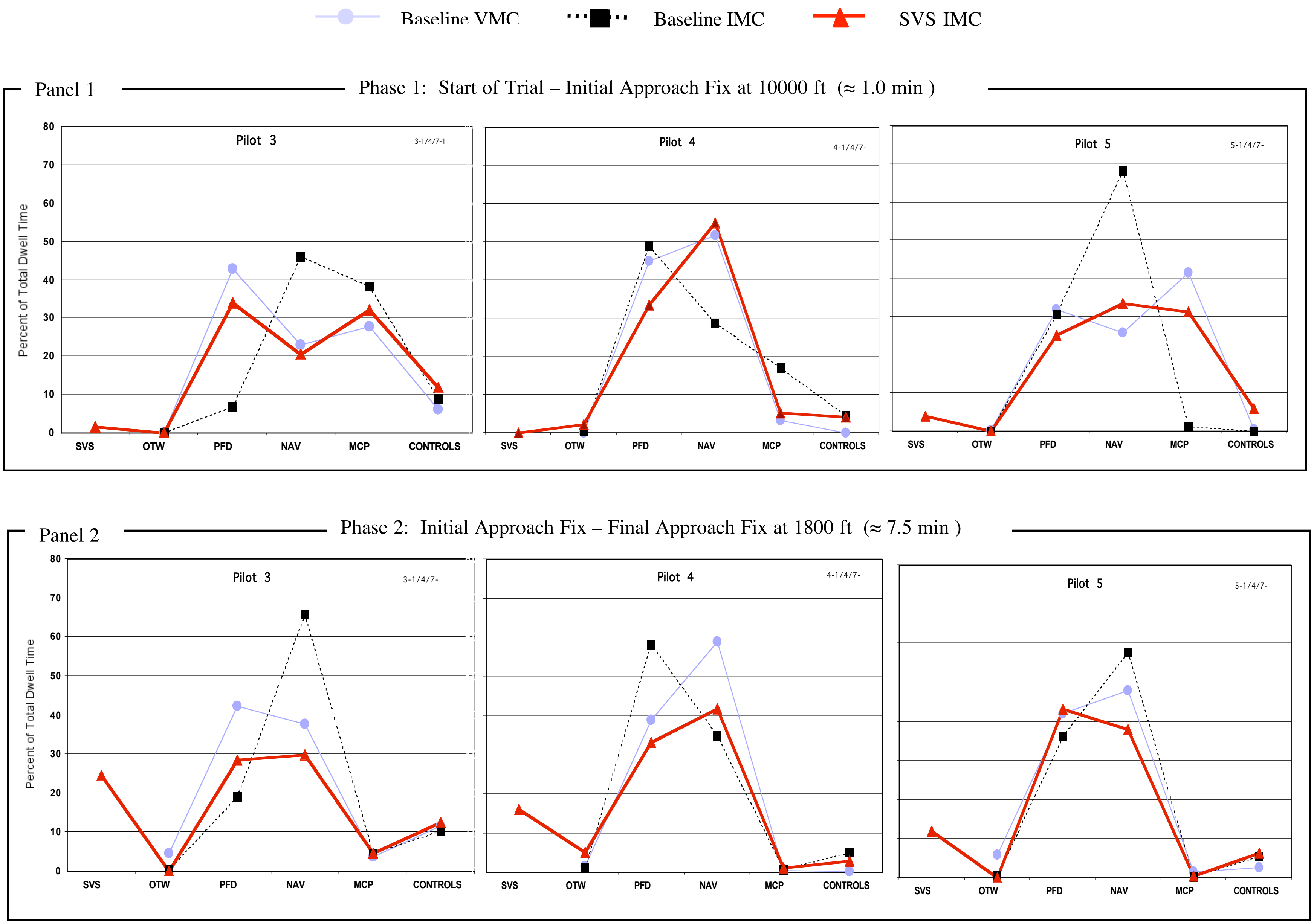

Figure 9a. Pilot dwell time percentages across 6 areas of interest during approach Phases 1 and 2 of nominal landing trials. Three display/visibility configurations are compared: Baseline VMC, Baseline IMC, and SVS IMC.

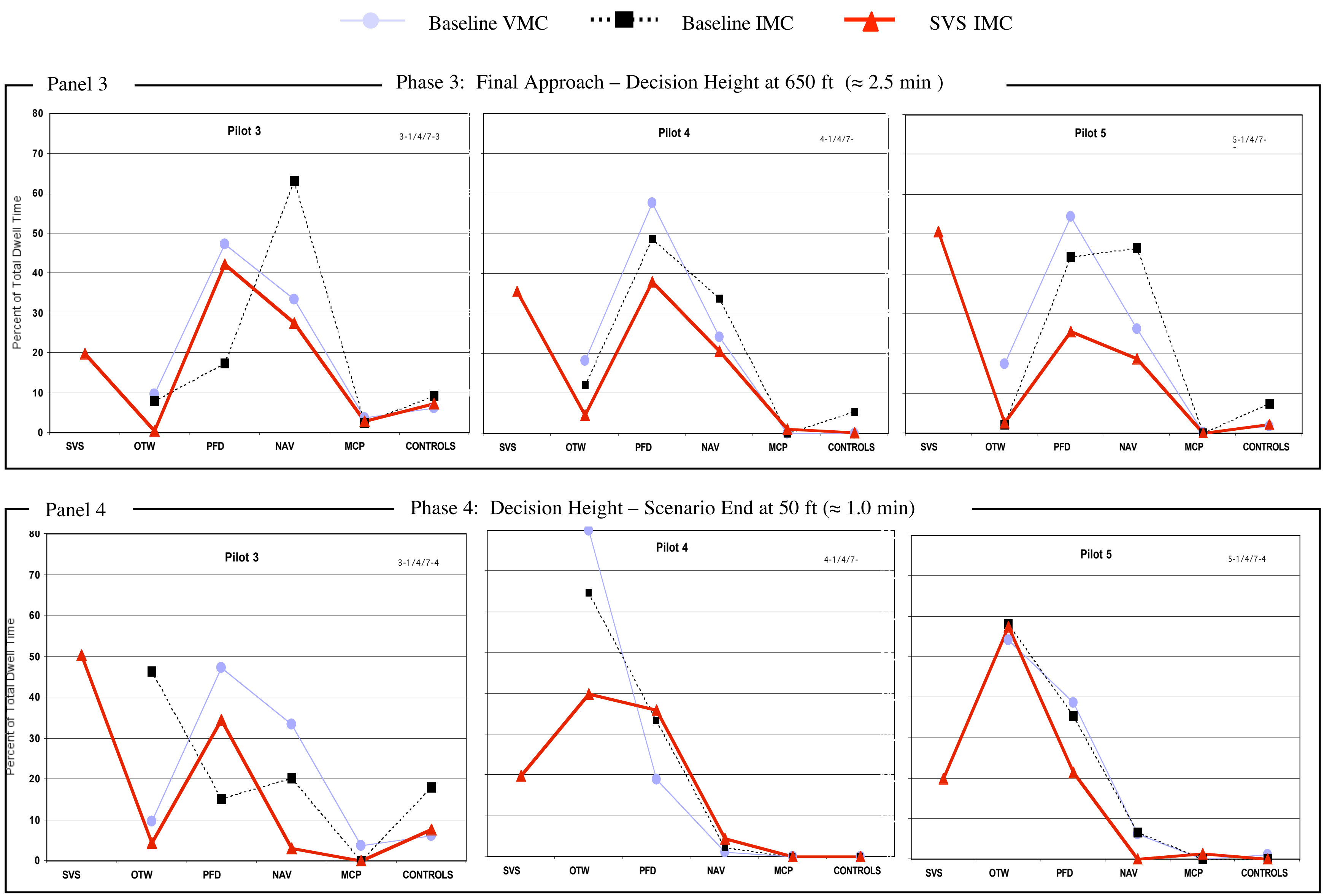

Figure 9b. Pilot dwell time percentages across 6 areas of interest during approach Phases 3 and 4 of nominal landing trials. Three display/visibility configurations are compared: Baseline VMC, Baseline IMC, and SVS IMC.

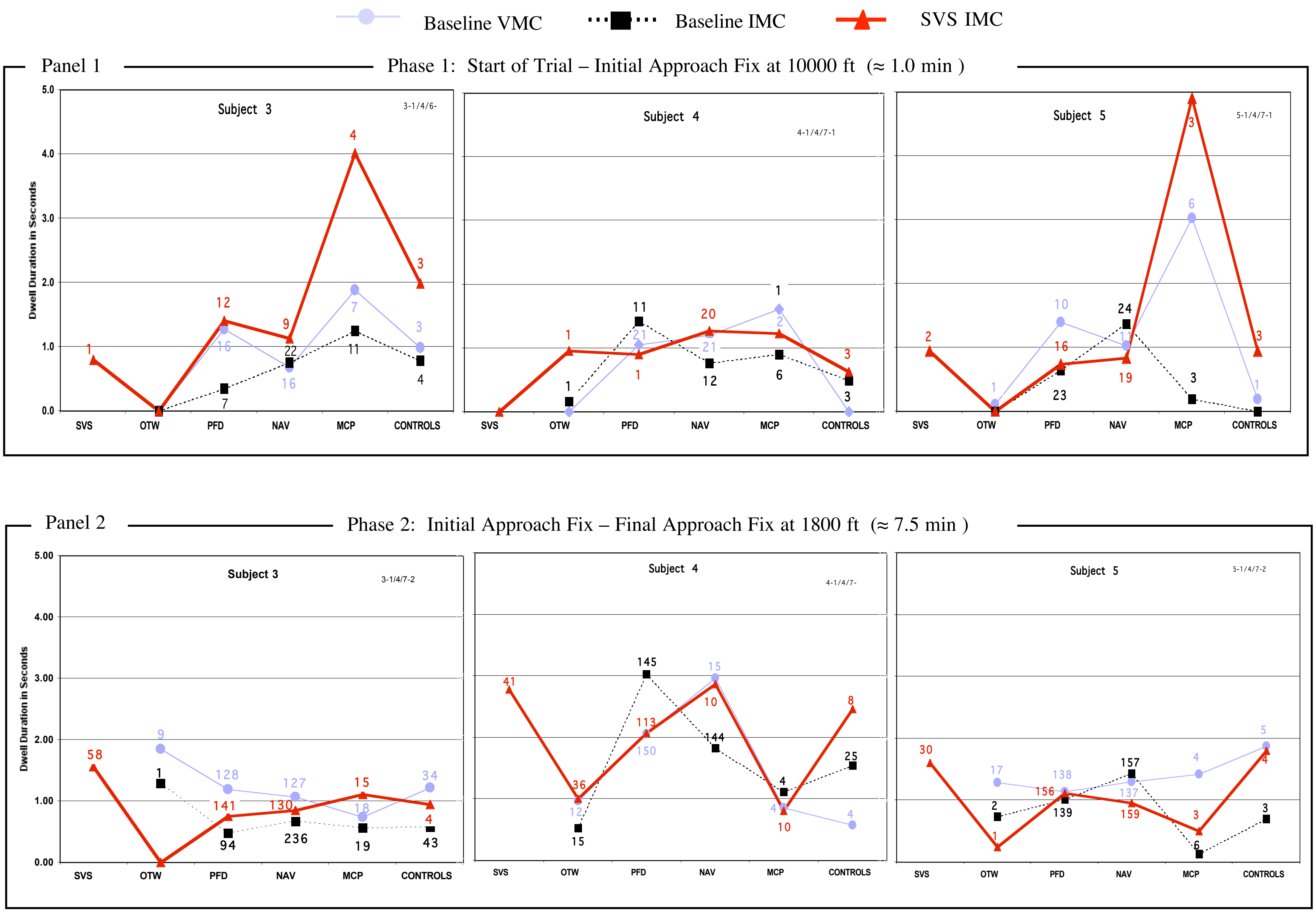

Figure 10a. Pilot mean dwell durations and dwell counts across 6 areas of interest during approach Phases 1 and 2 of nominal landing trials. Three display/visibility configurations are compared: baseline VMC, baseline IMC. And SVS IMC.

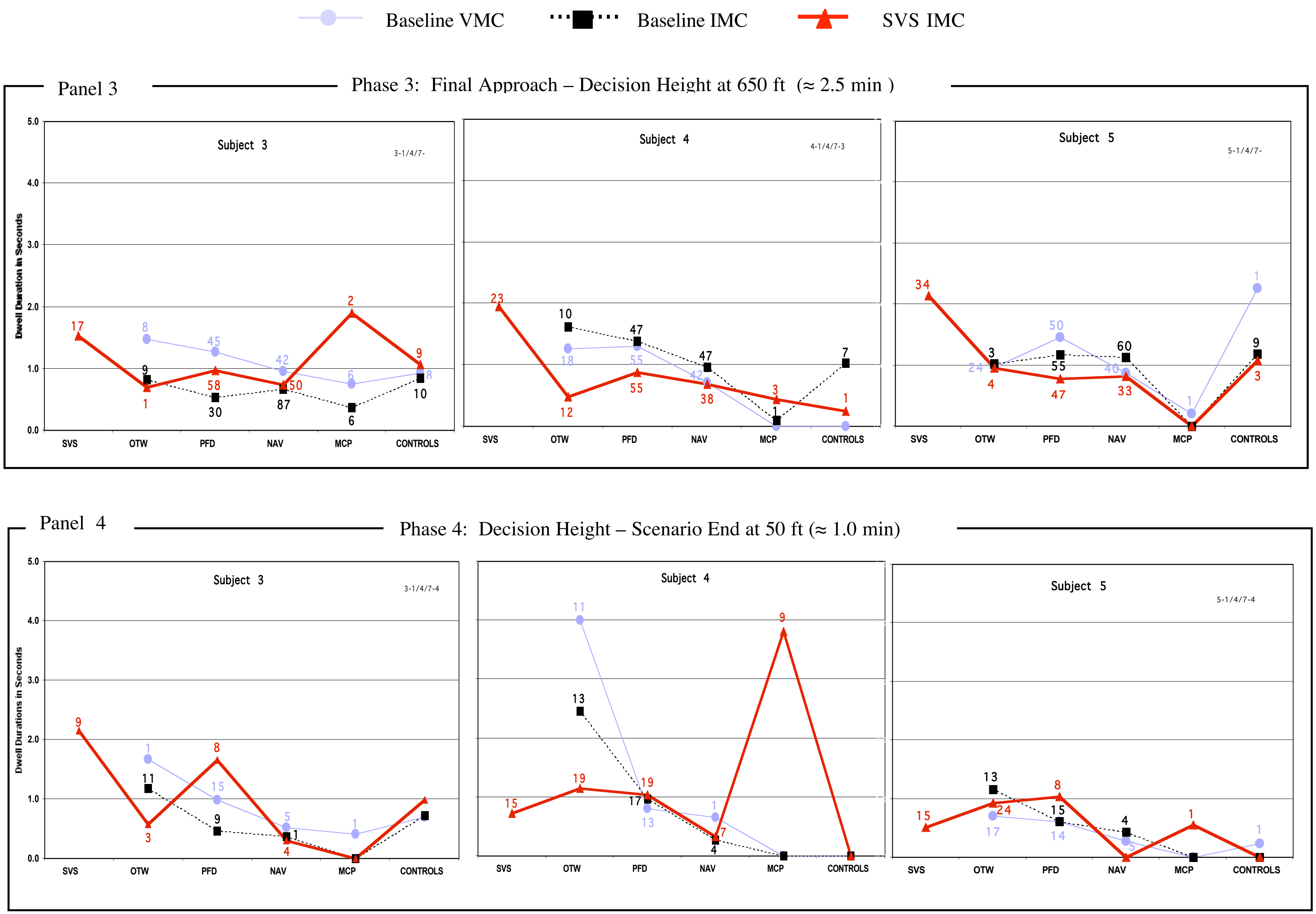

Figure 10b: Subject mean dwell durations and dwell counts across 6 areas of interest during approach Phase 3 and 4 of nominal landing trials. Three display/visibility configurations are compared: baseline VMC, baseline IMC, And SVS IMC.

In Phase 4 with clear visibility across all conditions and an overriding concern for flight path accuracy nearing touchdown, it could be expected that OTW viewing time would be very high and essentially equivalent across conditions. When available, the SVS display would provide no added fidelity over real world viewing, but would offer overlaid flight symbology redundant with the PFD and a flight path predictor useful for assisting landing accuracy. Consequently, it could also be expected that use of the SVS display at this stage would involve quick verification checks of flight symbology which would displace PFD usage and checks of the flight path predictor which, to some extent, might displace OTW viewing.

The data from Phase 4 indicate substantial differences in the visual strategy used by pilots. Pilot 5 best exemplifies the expectations stated above in that OTW viewing occupies the majority of visual attention in this final approach phase and is held nearly constant across conditions (54% - 58%). Pilot 4 devotes even more time OTW in Baseline VMC and IMC conditions, 80% and 65% respectively, but drops down to 40% when operating with the SVS display. For both Pilots 4 and 5, the data show numerous short duration dwells (mean = .6 sec; see Figure 10b) on the SVS display. Pilot 3 demonstrates a different pattern of usage with just 10% OTW time in Baseline VMC and down to just 5% OTW time with SVS. Unlike Pilots 4 and 5, Pilot 3 relies on the PFD and NAV displays and, when available, the SVS display to execute the landing. For this pilot, the usage assumptions regarding the SVS trials are reversed with the OTW view being used as a quick check (mean dwell = .6 sec) of the predominately watched SVS display.

SVS Usage

Pilots 4 and 5 exhibit a similar pattern of SVS utilization over the four phases of approach with little or no usage during Phase 1, increased usage during Phase 2 (14% average dwell time), predominate usage during the break-out and runway acquisition of Phase 3 (43% average dwell time), and, then, reduced usage during the short-final activities of Phase 4 (20% average dwell time). For Pilot 3, SVS usage is approximately constant through Phases 2 and 3 (25% and 20%, respectively), but predominates in Phase 4 (50%).

Comparing differences in dwell time percentages for each of the display regions between SVS and Baseline trials provides a sense of where time spent viewing the SVS display has been diverted. Averaged across the 3 pilots, SVS viewing during Phase 2 reduced NAV display usage 14%, PFD usage 4.5%, and OTW usage .5%. With more time spent viewing SVS in Phase 3, these usage reductions went to NAV display 16%, PFD 10%, and OTW 9%. In Phase 4 the average reductions associated with SVS viewing had shifted to NAV display usage down 9%, PFD usage down 1%, and, interestingly, OTW usage down 18%. It is observed that this last percentage drop in usage, though a mean of all three pilots tested, was the result of the visual performance of Pilots 3 and 4, but not Pilot 5. That two of three pilots selected a strategy of SVS usage during the final phase of approach (actually, the final two phases per discussion above) which substantially reduces OTW viewing is noteworthy.

PFD and NAV Display Usage

The PFD is an important and consistently accessed display with an overall mean percent dwell time across phases, pilots, and conditions of 36%. NAV display viewing figures most prominently during Phases 1 and 2, and when taken together with the PFD, provides the primary source of spatial/navigation awareness to pilots during that period (combined average dwell time of 78%). In Phase 3, when examining just the Baseline conditions, that combined average still remains a robust 81%. But with SVS, combined usage of the PFD and NAV displays drops to 58%. Most of this drop is in the usage of the NAV display which seems to diminish in relative importance with the increased reliance on the SVS display and the nearness of landing.

In Phase 4 the PFD still remains an important source of information and is the second most attended display during this final period. The NAV display, however, is used sparingly (with the exception of Pilot 3 in Baseline conditions) with very short dwell durations (mean = .36 sec).

Concluding Remarks

Pilot control inputs, eye-scan, questionnaire, and video recording data collected in part-task simulation helped guide corresponding modeling efforts by characterizing pilot performance with and without a SVS display during approach and landing operations. Additionally, study scenarios served to specify the task-environment and event conditions to be explored more extensively by the modelers in fast-time simulation. Lastly, performance data from the study provided a means for assessing the validity of resulting model predictions.

Of particular interest in this study were observed changes in visual performance associated with the use of a synthetic vision display. As noted in the selected analyses of the eye-tracking data, these changes included systematic reductions in the dwell times allocated to the NAV, PFD, and OTW displays, mediated by phase of approach. Despite such regularities, there were clear localized differences in SVS usage strategies between the three study pilots. Most significantly, the data shows two of the three pilots spent less time scanning OTW during final approach when the SVS display was available, even though there was unlimited forward visibility. Such usage suggests possible over-reliance on the SVS display.

There is, however, a more fundamental issue which might be derived from these findings. Though participating pilots in this study were made familiar with the functions and features of the SVS display, they were not instructed as to how to utilize the system during test scenarios. In a study of Electronic Moving Map (EMM) usage during taxiing (an advanced, head-down display concept), Graeber and Andre (1999) showed that "uninstructed" participants spent 25% more time viewing the EMM than their "usage instructed" counterparts. This extra head-down, eyes-in time was seen as counter to the potentially performance benefits of EMM and pointed to the importance of procedural training. Similarly, the divergent usage strategies exhibited by pilots in this study highlight the need to develop and train appropriate usage procedures in advance of the deployment of SVS displays.

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